Anisotropic basal roughness at scales close to the transition wavelength beneath upper Thwaites Glacier

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Thwaites Glacier is a large, fast-moving and rapidly changing glacier in the Amundsen Sea catchment of West Antarctica. Recent ice-flow models suggest that its basal conditions exert a strong influence upon its ice-flow patterns and that they vary significantly across the glacier. To clarify the relationship between its basal conditions and its flow, we are conducting ground-based geophysical studies (radar, seismic and GPS) along a central flowline of the glacier. Here we present preliminary results from 150-MHz ice-penetrating radar data collected during the 2008-9 Antarctic field season within an area of upper Thwaites Glacier approximately 37 km long (longitudinal to flow) and 14 km wide (transverse to flow) that crosses onto a transverse "ridge" in the inferred basal shear stress. There are several longitudinal ridges in the basal topography and a transverse step ~ 10 km upstream of the ridge in the modeled basal shear stress. The basal echo intensities along the transverse lines are significantly lower than those along the longitudinal lines, and this difference is consistent with the radar-wavelength-scale (1.1 m) roughness inferred from the basal topography. For presently glaciated beds, anisotropy in the basal roughness at this length scale has not been previously observed, and it is close to the predicted transition wavelength (~0.5-1 m), where regelation and creep around obstacles are of equal importance in basal sliding and where erosion should peak. Within our study area, longitudinal bumps whose wavelength is similar to the transition wavelength are less than half the height of transverse bumps at the same wavelength, which implies that the bed is preferentially eroded in the longitudinal direction. This inference is consistent with previous observations of deglaciated bedrock near alpine glaciers. We also find that the spatial variation in the basal roughness anisotropy is correlated with the spatial variation in modeled basal shear stress; areas of low modeled basal shear stress, which implies that the bed is softer/weaker, have larger basal roughness differences. Finally, the radar-observed roughness differences are consistent with acoustic basal reflectivity differences inferred from reflection-seismic data, and we will soon compare the radar results with the basal lithologies inferred from amplitude-versus-offset seismic data collected along two widely separated transverse lines. These observations provide clues regarding the small-scale controls on basal sliding and their relationship to the large-scale ice-flow patterns of a major Antarctic glacier.